Boyle's Law Lab H

Pre-Lab Discussion

The apparatus you will use in this experiment is shown in Figure 19-1. It consists of a plunger that fits into a cylinder. Fitted to the bottom of the plunger is a gasket made of rubber or plastic that has been lubricated with a liquid silicone. This gasket provides an airtight seal against the walls of the cylinder. In this experiment, you will trap a sample of air in the cylinder beneath the plunger. You will then add four books, one by one, to the platform on top of the plunger. After adding each book, you will measure the volume of the air trapped beneath the plunger to see what effect the increase in pressure is having on the volume of the air sample.

Weight and pressure are not the same physical quantities. However, in this experiment you can use the weight of your chemistry book as a unit of pressure because the weight of two books exerts twice as much pressure as the weight of one book, provided the weights are always applied to the same area. In this experiment, the weights are applied to the same area, namely, the area of the gasket that is in contact with the sample of air.

When you measure the volume of gas trapped below the piston, your measurements will be slightly off because of the existence of friction between the gasket on the plunger and the walls of the cylinder. Every time you place a book on the platform, friction will prevent the plunger from falling as far as it would in the absence of friction. Therefore, every measurement of volume will be slightly larger than it should be. However, there is a way of minimizing the effect of friction. This can be done by making a second series of volume measurements. During the first series, already described above, you gradually add weight, which, because of friction, produces volume readings that are slightly larger than they should be. During the second series, you remove the books that were added during the first series. Each time you remove a book, friction will prevent the plunger from rising as far as it would in the absence of friction. As a result, all the volume readings made during the second series will be slightly smaller than they should be. This effect is just opposite to the effect during the first series, when the values were too large. By averaging the two series of readings, the distortions produced by friction will tend to cancel each other out.

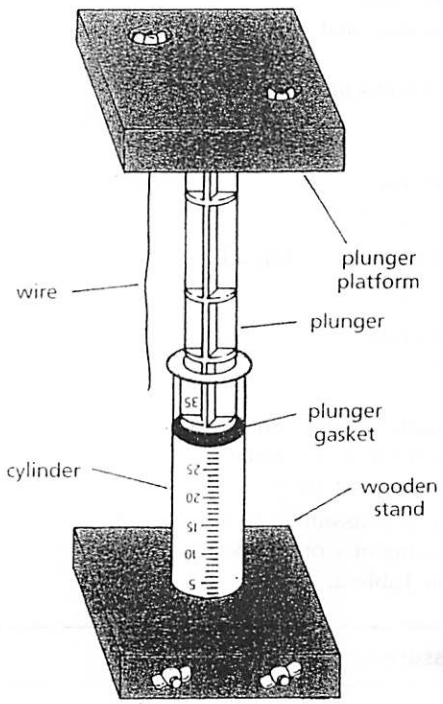

Figure 19-1

Purpose

To investigate the pressure/volume relationship of a gas.

Equipment

plunger and cylinder apparatus (Boyle's law apparatus)
safety goggles
lab coat or apron

Safety

Follow all general rules for laboratory safety, and always wea goggles and a lab coat or apron when working in the lab.

Procedure

1. Carefully insert the plunger into the cylinder. Gently push down on the platform over the plunger until the bottom of the plunger is at the graduation marked *30*. Hold the plunger in that position for a second or two, and then let go. What happens? Why?

2. Remove the plunger from the cylinder. With the wire running straight down alongside the plunger, put the wire into the top of the cylinder first, and then begin pushing the bottom of the plunger into the cylinder. The wire will open up a space in the gasket so that air can escape from the cylinder as you push downward. Stop when the bottom of the plunger reaches the 30-mL mark. While holding the plunger at the 30-mL mark, pull the wire out of the cylinder. When you remove your hand, the bottom of the plunger should remain at the 30-mL mark.

3. You are now going to apply larger and larger pressures to the sample of air by resting more and more weight on the platform above the plunger. A convenient weight to use in this experiment is the weight of your chemistry textbook. Gently lower one book onto the platform so that the center of the book is over the center of the platform. Record in Column 2 of Data Table 1 the volume occupied by the sample of air when one book is resting on the platform.

4. Following the step described above, gently rest a second book on top of the first book. Record the new volume in Table 1.

5. Repeat the step for a third book, then a fourth book.

6. As mentioned in the pre-lab discussion, all the measurements you just made are slightly too large because of friction. You will now make a second series of the measurements while books are being removed from the platform. With four books still on the platform, begin the second series by gently pushing down on the top book until the piston falls about 1 cm. Gradually lift your hand off the top book. Record the volume in Column 3 of Table 1.

7. Gradually lift the top book from the platform, leaving three books on the platform, and record the new volume.

8. Gradually lift one book at a time and each time record the new volume, including the volume when no books are on the platform.

DATA TABLE 1 Volume of a Sample of Gas at Different Pressures

Trial	Column 1 Pressure (Number of Books on Platform)	Column 2 Volume (Series 1)	Column 3 Volume (Series 2)	Column 4 Av. Volume (Average of Series 1 & Series 2)	Column 5 $P \times V$ Product (Col. 1 × Col. 4)

Calculations

1. Record in Column 4 the average of the volumes in Columns 2 and 3.

2. For each trial, multiply the pressure (the number of books) by the average volume and record your results in Column 5 of Data Table 1. Do you get the same product for $P \times V$ for each trial, in accordance with Boyle's law?

3. Assume that only some of the pressure exerted on the sample of air comes from the weight of the books and that there is some additional pressure (some extra pressure) from some other source. Use the symbol x to stand for this extra pressure. Assume also that this extra pressure is the same for all trials of the experiment. Then the total pressure on the sample of air during any of the trials is the sum of these two pressures:

$$\text{Total pressure} = \text{pressure from books} + \text{extra pressure}$$
$$P_{\text{total}} = P_{\text{books}} + x$$

When 2 books are resting on the platform:

$$P_{\text{total}} = 2 \text{ books} + x$$

4. Under the assumption given directly above, find the "extra pressure." Because, by Boyle's law, *Pressure* × *Volume* is supposed to equal a constant, *Pressure* × *Volume* for one trial should equal *Pressure* × *Volume* for any and all other trials.

$$P_a \times V_a = P_b \times V_b \qquad \textbf{(Eq. 1)}$$

where P_a and V_a = pressure and volume for one trial,
and P_b and V_b = pressure and volume for another trial.

Using the data for Trials 1 and 2, the math for Equation 1 looks like this:

Trial 1 (1 book on platform)				Trial 2 (2 books on the platform)			
P_1	×	V_1	=	P_2	×	V_2	
(1 book + x)	×	(Volume)	=	(2 books + x)	×	(Volume)	**(Eq. 2)**
↗				↗			
Your calculation of average volume for Trial 1				Your calculation of average volume for Trial 2			

Using the data you recorded in Data Table 1, solve Equation 2 for x. Show your work below. Use a clean sheet of paper if you need more space. Because the unit of pressure is the *book*, x will have as its unit the *book*.

5. Put the value you obtain for x in Table 2. Because it is assumed that this extra pressure is the same for all trials, put your value of x on all five lines of Column 2. Then fill out Columns 3, 4, and 5 in Table 2.

DATA TABLE 2 The *PV* Product Using the Extra Pressure

Trial	Column 1 Pressure (Number of Books on Platform)	Column 2 The Extra Pressure (x)	Column 3 The Total Pressure (Columns 1 + 2)	Column 4 Av. Volume (Average of Series 1 & Series 2)	Column 5 $P \times V$ Product (Columns 3 × 4)

Conclusions and Questions Part I Answer in your Nok book

1. For which trial would the data in Data Table 1 lead you to believe there must be some pressure being exerted on the sample of air in addition to the weight of the books? Explain.

2. When you used the total pressure (pressure from the weight of the books + extra pressure) to obtain the *PV* product in Table 2, did you obtain the same *PV* product for all five trials in accordance with Boyle's law? Explain.

3. Formulate a hypothesis to explain what causes the extra pressure referred to in question 1

4. Design an experiment to test the hypothesis you formulated as your answer to question 3.

5. How would you go about testing to see whether the cylinder, with the plunger inserted, is really airtight?

6. Devise an experimental procedure to determine how much inaccuracy there might be in the measurements of volume in this experiment.

Part II Graphing V + P

Calculations

Show your computations. Place your answers in your Calculations Table.

1. Calculate the average volumes of the three trials for weights 0–4. Record in your Calculations Table.
2. Calculate the inverse for each of the average volumes. Example: If the average volume for three weights is 26.5 cc, then $1/V = 1/26.5\ cc = 0.0377\ cc^{-1}$.

Questions

1. Plot a full-page graph of pressure versus volume. Use the graph on the next page as a model. Since the number of weights added to the piston is directly proportional to the pressure applied to the gas, we can use the number of weights to represent the changes in pressure. Plot the number of weights on the horizontal axis and the adjusted volume on the vertical axis. Draw the smoothest curve that goes through most of the points. Does your graph indicate that a change in volume is directly proportional to a change in pressure? Explain.
2. Plot a full-page graph of pressure versus 1/volume. Use the below graph as a model. Plot pressure on the horizontal axis and 1/volume on the vertical axis. Draw the best line that goes through the majority of the points. What do you conclude about the mathematical relationship between pressure applied to a gas and its corresponding volume?

Nok: Graphs should be done on a computer and taped into your notebook.